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Semi-Annual Report on

LASER SURFACE INTERACTIONS: CREATION AND DETECTION OF ATOMICALLY CLEAN SURFACES

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Principal Investigator: Professor Harold P. Smith, Jr.

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INTRODUCTION

Advancing technology and increased interests in areas of surface physics, such as the behavior of surfaces exposed to the hard vacuum of the space environment, thin film technology, and surface catalysis have created a need for the development of a convenient and reliable technique for producing atomically clean surfaces. Previous techniques have included high-temperature bulk annealing, sputter cleaning, vacuum cleaving, and chemical cleaning, to mention the most common. Each technique has shortcomings or disadvantages of inconvenience or inapplicability to the surface being cleaned.

As a result, the NASA Lewis Research Center, through the University of California Space Sciences Laboratory, has sponsored a research program beginning in Fall, 1966, to investigate the applicability of laser-surface bombardment for the production of atomically clean surfaces. The laser cleaning mechanism is intense heating of a localized portion of the material surface, essentially resulting in the thermal evaporation of only surface layers of material. The thickness of these surface layers can of course be controlled by the intensity of the laser pulse. The advantages of this cleaning technique are the simplicity of the equipment (a laser external to the vacuum system that has, at most, an additional port for the laser) and universal applicability to all materials.

This document is submitted as a report of progress in this investigation for the period from October 1966 through March 1967.

SURFACE CLEANING AND DETECTION

In the above discussion of the potential of laser cleaning, no mention has been made of the method of identifying a clean surface. Two methods will be used for this purpose. One is the use of LEED

(Low Energy Electron Diffraction) by which the diffraction of low-energy electrons can identify an atomically-ordered surface; the other method is by high-energy ($\sim$ 100 keV) proton-induced characteristic X-rays of the surface contaminants.

The Laser-Leed experimental arrangement is shown schematically in Figure 1. The target to be cleaned is aligned perpendicular to the axis of the laser and then pulsed by the Q-switched laser with pulses that range in peak power density from 20 to 200 megawatts/cm^2 and have total energy densities of 2 joules/cm^2. After laser bombardment the target is annealed and is rotated back into alignment with the electron gun, and the diffraction pattern is observed. From the type and intensity of the diffraction pattern it is possible to identify the type of surface structure or its contamination.

During the previous six-month period, the LEED device was received from the manufacturer and installed in our laboratory. Following the initial checkout an aluminum target was prepared and installed in the LEED. Annealing at 600° C for 40 hours conditioned the surface to give the expected aluminum diffraction pattern. To observe the effect of a laser pulse in disordering the surface, 1.2 joules/cm^2, 30 megawatts/cm^2 pulses caused no degradation of the pattern, but did produce sizable bursts (from 10^{-10} Torr to 10^{-8} Torr). These pressure bursts presumably come from gases desorbed from the target and the vacuum chamber by reflected laser light.

Focusing the laser pulse to higher energy densities caused a degradation of the diffraction pattern that was readily removed by annealing at 600° C for 10 hours. For energy densities above approximately 50 megawatts/cm^2 there is visual damage caused to the surface. Even at this extreme the diffraction pattern was partially recovered by annealing.

Having thus established the capability of the laser to disorder the surface by heating and evaporation, and also having established the energy and power densities neccessary to achieve this, it is expected that during the next six months attempts will be made to create atomically clean surfaces for LEED. This will entail the preparation of a nickel surface by conventional methods to identify its structure and then the intentional contamination of this surface by oxygen. The cleaning potential of the laser will then be investigated by attempting to desorb the contaminating oxygen. Following these experiments, an unprepared nickel surface will be laser-bombarded to create an atomically clean surface.

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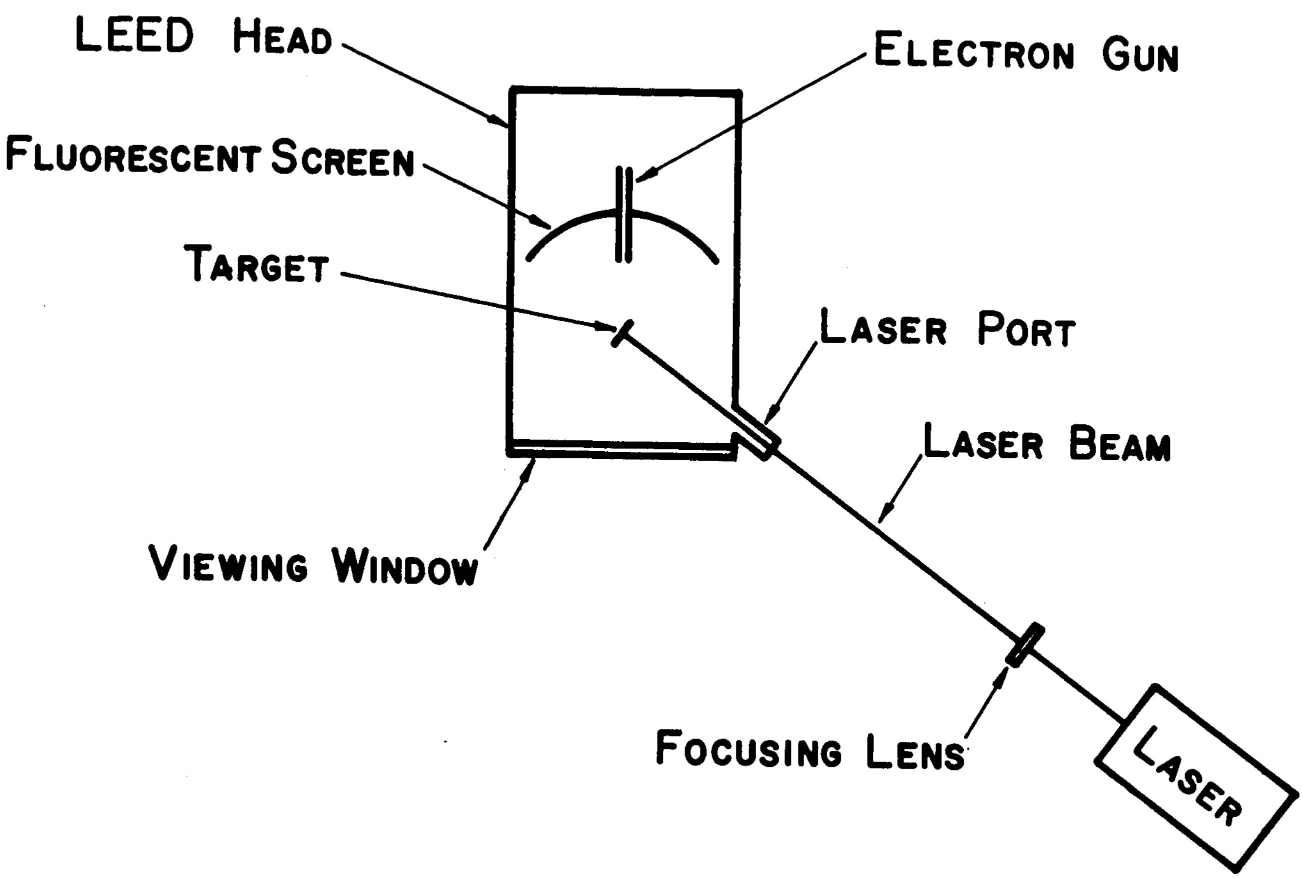

Figure 1. Schematic showing arrangement by which LEED targets are bombarded by laser pulses.